University of Kasdi Merbah Ouargla
Faculty of New Technology of Information and Communiction
Department of Electronics and Communications
Option : Automatic
Type 2 Fuzzy Control for Twin Rotor (TRMS)

present by : Reguibi Noureddine Omar Bahloul

Promoter : Mr.Kafi Mohammed Redouane

Abstract: The helicopter dynamic includes nonlinearities, parametric uncertainties and is subject to unknown external disturbances. Such complicated dynamics involve designing sophisticated control algorithms that can deal with these difficulties. In this paper, a type 2 fuzzy logic controller is proposed for TRMS (twin rotor mimo-system) control problem. Using triangular membership functions and based on a human operator experience, two controllers are designed to control the position of the yaw and the pitch angles of the TRMS. Simulation results are given to illustrate the effectiveness of the proposed control scheme. [1]

Keywords: Type 2 fuzzy logic • Dynamic modeling • TRMS system • Nonlinear system [1]

Introduction :

Helicopters are one of the most manoeuvrable and versatile platforms. They can take-off and land without a runway and can hover in place. These capabilities have brought about the use of autonomous miniature helicopters. For these reasons, there is currently great interest in using these platforms in a wide range of civil and military applications that include traffic surveillance, search and rescue, air pollution monitoring, area mapping, agriculture applications, inspection of bridge and building constructions. For performing safely many types of these tasks, high manoeuvrability and robustness of the controllers with respect to disturbances and modeling errors are required. This has generated considerable interest in the robust flight control design[1] for exemple fuzzy sliding and fuzzy integral sliding controllers, type-1 fuzzy controller, type-2 fuzzy controller and so on . in this work we will just use type-2 fuzzy controller Due to its effectiveness in handling nonlinearities, uncertainties and parameter variations,(more attuned to reality than type-1)

TRMS set description

The description of the TRMS setup in this section refers to the mechanical part and the control aspect. For details on the mechanical and electrical connection, the interface and an explanation of how the signals are measured and transferred to the PC, refer to the 'Installation & Commissioning' manual.

As shown in Figure 1, the TRMS mechanical unit consists of two rotors placed on a beam together with a counterbalance. The whole unit is attached to the tower allowing for safe helicopter control experiments.

Usually, phenomenological models are nonlinear, that means at least one of the states (i – rotor current, θ – position) is an argument of a nonlinear function. In order to present such a model as a transfer function (a form of linear plant dynamics representation used in control engineering), it has to be linearised. According to the electrical-mechanical diagram presented in Figure 1 the non linear model equations can be derived. [2]

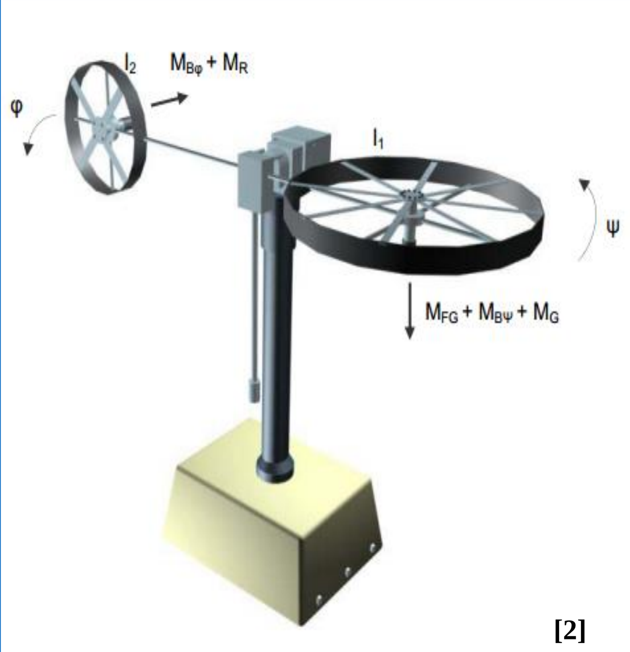

Figure 1 TRMS phenomenological model

TRMS model

Every control project starts with plant modelling, so as much information as possible is given about the process itself. The mechanical-electrical model of the TRMS is presented in Figure 1.

As far as the mechanical unit is concerned the following momentum equations can be derived for the vertical movement:

$$I1 \cdot \ddot{\psi} = M1 - MFG - MB\psi - MG$$

Where

$M_1 = a_1 .\tau_1^2 + b_1 .\tau_1$ - nonlinear static characteristic

$M_{FG} = M_g .\sin\psi$ - gravity momentum

$M_{B\psi} = B_{1\psi} .\dot{\psi} + B_{2\psi} .\mathrm{sign}(\dot{\psi})$ - friction forces momentum

$M_G = K_{gy} .M_1 .\dot{\varphi} \cos\psi$ - gyroscopic momentum

The motor and the electrical control circuit is approximated by a first order transfer function thus in Laplace domain the motor momentum is described by:

$$r_1 = \frac{k_1}{T_{11}s + T_{10}} .u_1$$

Similar equations refer to the horizontal plane motion:

$$I2 \cdot \ddot{\varphi} = M2 - MB\varphi - MR$$

Where

$M_2 = a_2 .\tau_2^2 + b_2 .\tau_2$ - nonlinear static characteristic

$M_{B\psi} = B_{1\varphi} .\dot{\psi} + B_{2\varphi} .\mathrm{sign}(\dot{\varphi})$ - friction forces momentum

MR is the cross reaction momentum approximated by:

$$M_R = \frac{k_c\,(T_0 s + 1)}{T_p s + 1} .\tau_1$$

Again the DC motor with the electrical circuit is given by:

$$r_2 = \frac{k_2}{T_{21}s + T_{20}} .u_2$$

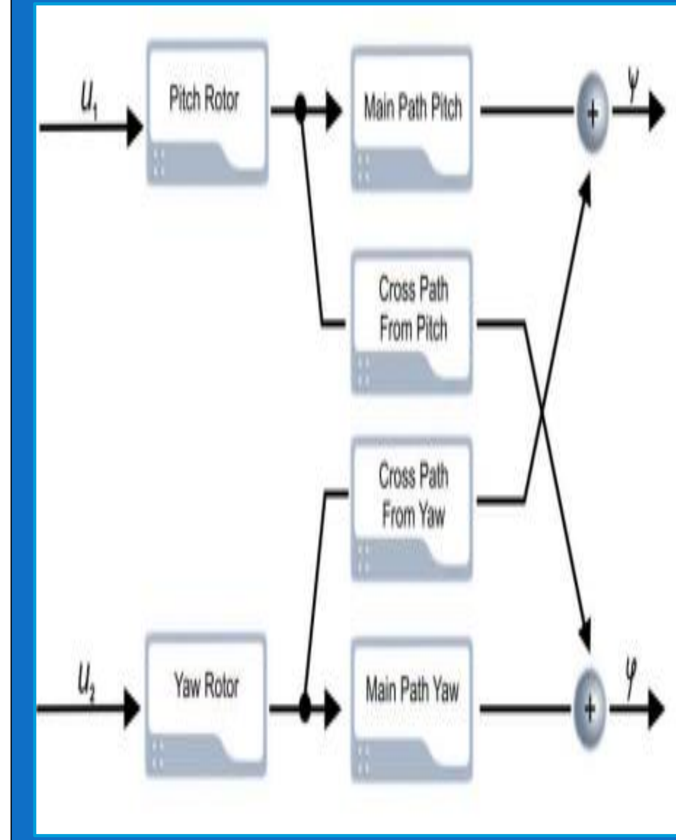

Figure 2 TRMS simplified system schematic [2]

The TRMS is controlled with two inputs the u1 and u2. The dynamics cross couplings are one of the key features of the TRMS (Figure 2). The position of the beams is measured with the means of incremental encoders, which provide a relative position signal. Thus every time the Real-Time TRMS simulation is run one must remembe that setting proper initial conditions is important. [2]

Control algorithm of t he TRMS

The control objective is to design control laws to force the helicopter's positions to track their pre-defined time-dependent desired values. This objective is to be achieved under unknown or uncertain system's dynamics. The fuzzy control strategy is based on a human operator experience to interpret a situation and initiate its control action.

A block diagram for the fuzzy controller is illustrated in Figure 3 . Given the two position errors [1]

$$e_\psi = \varphi - \psi_d \qquad \dot{e}_\psi = \dot{\varphi} - \dot{\psi}_d$$

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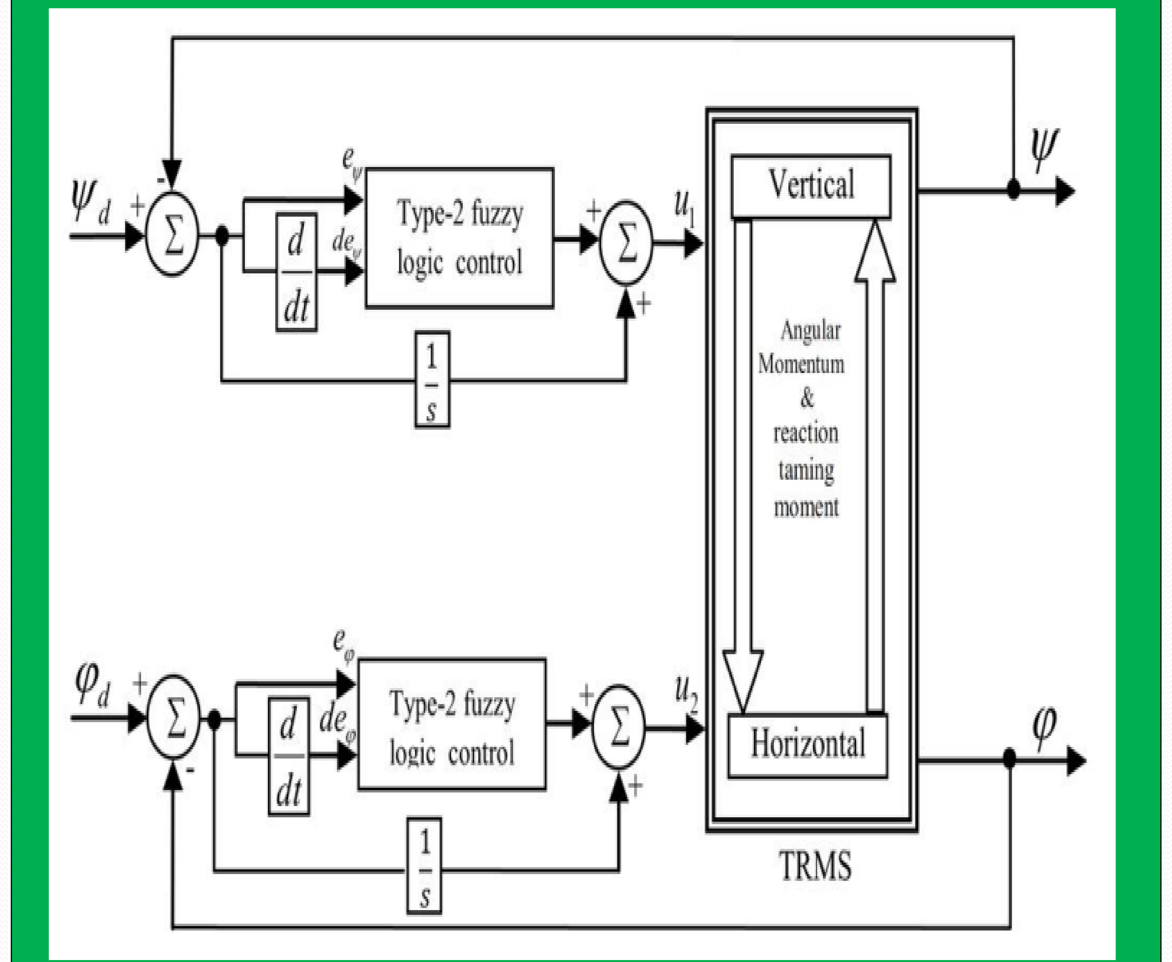
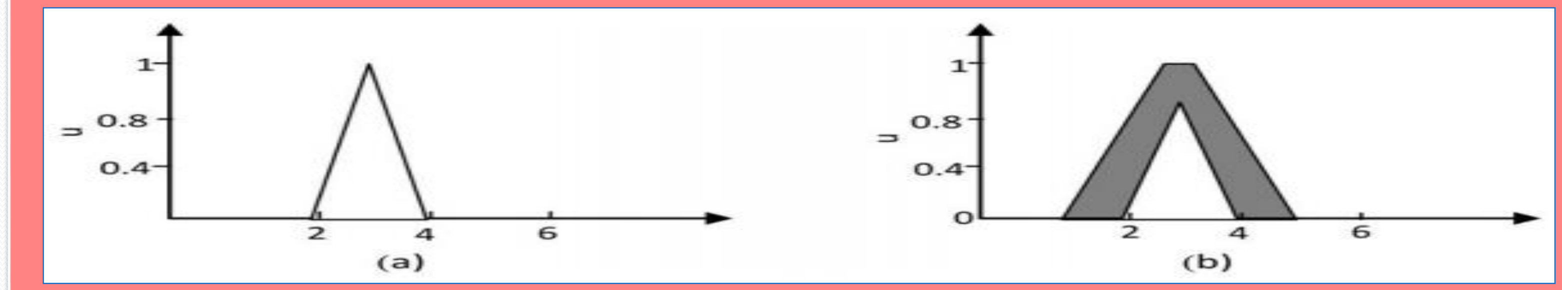


Figure 3. Block diagram of the proposed fuzzy type-2 control scheme

Brief review of type-2 fuzzy logic control

Type-1 and type-2 fuzzy logic are mainly similar. However, there exist two essential differences between them which are: the membership functions forms and the output processor. The interval type-2 fuzzy controller includes: fuzzifier, inference engine, rules bases, type reduction and a defuzzyfier . This section reviews the main [1] characteristics of type-2 fuzzy logic systems and gives some impor tant concepts associated with them [1]



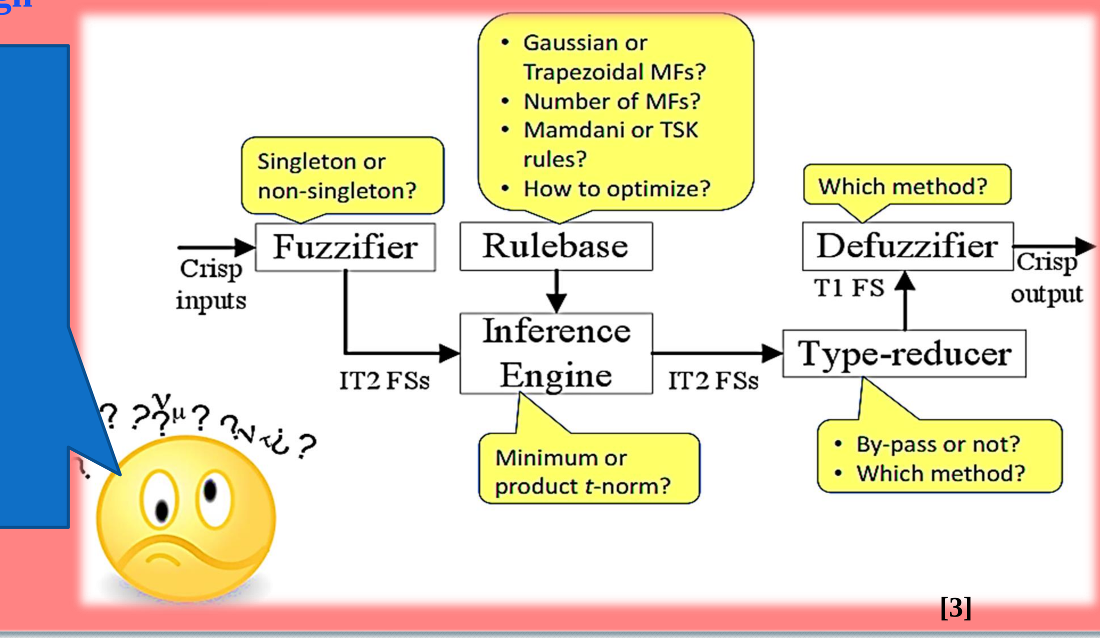
Now it's time to revisit IT2 FLS design

Fuzzification: transforms the input variable to a fuzzy sets .

Inference: it calculates the fuzzy set associated with the output controller, it is through the fuzzy operations and aggregation rules

Type-reducer: type-reducer is needed to convert them into a type-1 fuzzy set before defuzzification can be carried out

Defuzzification: Turns fuzzy inference part resulting in an actual physical quantity Applicable in the process.(To get a crisp output from a type-1 fuzzy logic system)



Conclusion :

A new approach for the attitude stabilization for the two degrees of freedom helicopter (TRMS) is resented. This approach is based on the type-2 fuzzy logic controller. The main strength of the proposed control algorithm is its robustness with respect to parametric uncertainties and noise measurement. The proposed approach will be applied, in simulation, to the control of two degrees of freedom helicopter in the presence of parametric uncertainties and noise measurement. [1]

References :

[1] Samir Zeghlache , Kamel Kara, Djamel Saigaa1 ; Type-2 Fuzzy Logic Control of a 2-DOF Helicopter (TRMS system) Cent. Eur. J. Eng. • 4(3) • 2014 • 303-315 , DOI: 10.2478/s13531-013-0157-y

[2] Twin Rotor MIMO System Manual, Feedback Instruments Ltd., UK (2006)

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